Next Generation Systems Engineering – An OSD Perspective

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Current Situation

What we need to do better

Requirements

- Adapting to changing conditions
- Matching operational needs with systems solutions
- Overcoming biases of Services and others
- Moving to transform military

PPBES

- Laying analytical foundation for budget
- Aligning budgets with acquisition decisions

Sustainment

- Controlling O&S costs
- Reducing logistics tails

Acquisition

- Acquiring systems-of-systems
- Making system decisions in a joint, mission context
- Transitioning technology
- Assessing complexity of new work and ability to perform it
- Controlling schedule and cost
- Passing operational tests
- Ensuring a robust industrial base

USD(AT&L) Imperatives

- “Provide a context within which I can make decisions about individual programs.”
- “Achieve credibility and effectiveness in the acquisition and logistics support processes.”
- “Help drive good systems engineering practice back into the way we do business.”

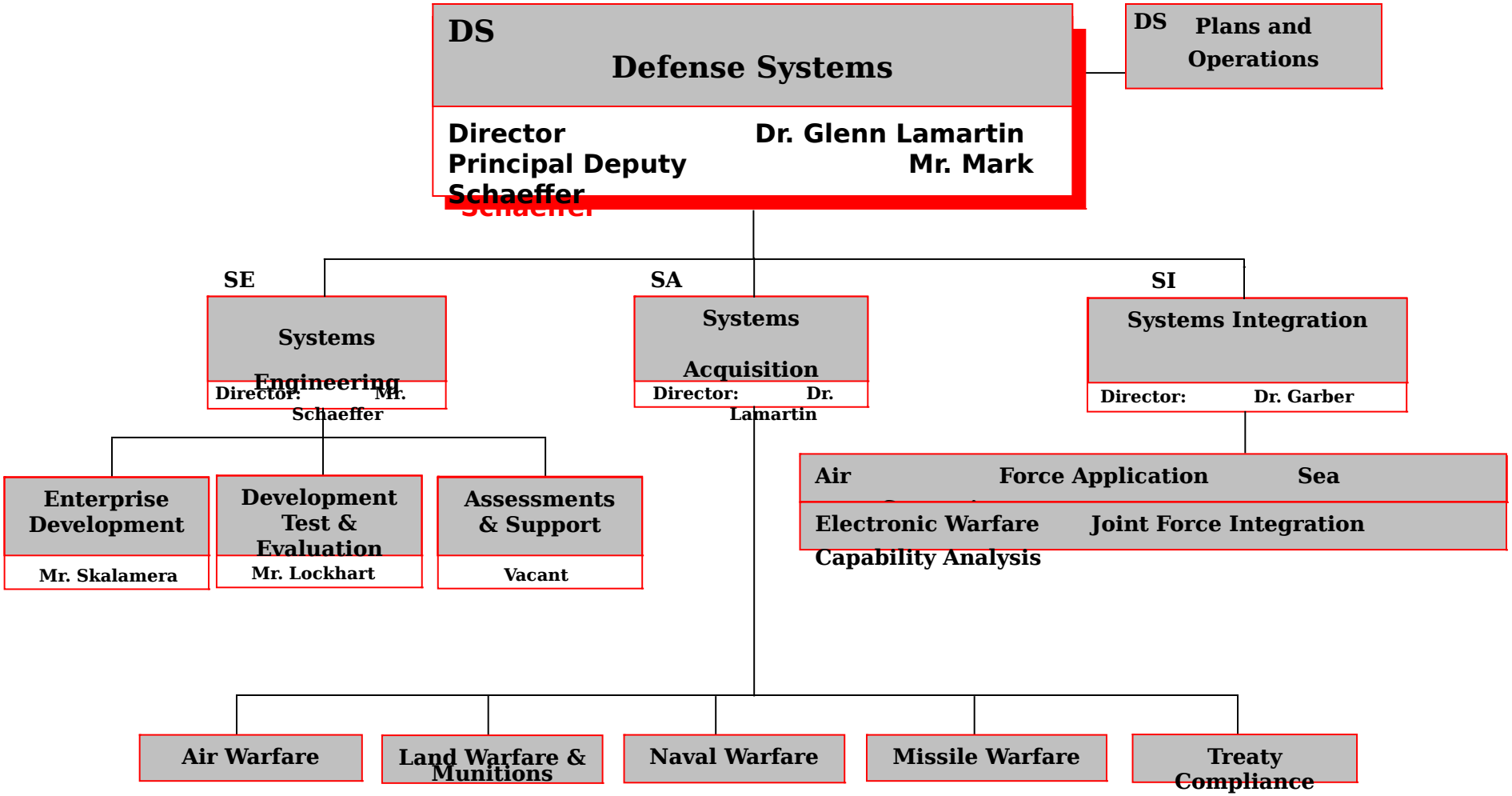
How Defense Systems is Responding

- Instituted a new Systems Integration organization
  - Extends and complements work of former Interoperability Office
  - Engaging OSD, Joint Staff, Services, and COCOM staffs to define joint integrated architectures
  - Synchronizing the requirements, acquisition, and budget processes
- Warfare offices (formerly Strategic and Tactical Systems) tailoring the application of DoD 5000
  - Leading IPT process for program oversight and review
  - Role is to help programs succeed
- Formed a new Systems Engineering organization
  - Institutionalizing Systems Engineering across the Department
  - Setting policy for implementation, capturing best practices, setting standards for training and education
  - Enhancing emphasis on system assessment and support

Director, Defense Systems

- Principal advisor to the Under Secretary of Defense (Acquisition, Technology & Logistics) through the Principal Deputy Under Secretary of Defense (Acquisition, Technology & Logistics)
  - Technical review, evaluation, and oversight of strategic and tactical DoD development and acquisition programs
  - Chairs Overarching Integrated Product Teams in the Defense Acquisition Board process
  - Enables effective joint and combined operations through the development of system of systems capabilities
  - Integration and implementation of policies regarding system integration and interoperability of systems used in coalition warfare
  - Facilitates timely and affordable fielding of effective warfighting capabilities by promoting the application of a sound engineering management approach to the Department’s acquisition process

Defense Systems Organization



Systems Engineering
Enterprise Development

- Define “good systems engineering”
  - How to plan. How to gauge progress.
- Find, capture, and share best practices
- Educate the workforce (industry and government)
- Develop systems engineering tools
- Engage industry, services, academia, professional associations, allies
- Establish systems engineering policy and procedures

Systems Engineering
Assessment and Support

- Focal point for outreach to individual programs
- Directs, manages, and coordinates special studies and reviews addressing systems engineering and software
- Leads special projects and DoD studies relating to software issues
- OSD focal point for software acquisition process improvement
  - Leads the OSD Tri-service Assessment Initiative providing independent assessments to DoD program managers
- Recommends changes to Department systems engineering policies and procedures

Systems Engineering
Development Test & Evaluation

- A critical part of good systems engineering
- Ensures thorough test planning and assignment of resources
- Provides indication of technical maturity
- Verifies system performance
- Confirms the design meets specifications
- Stressing expanded use of models and simulation, especially for systems of systems
- Recommends changes to Department DT&E policies and procedures
- Key determinant of successful OT&E

SE Challenges and Opportunities

“Help drive good systems engineering practice back into the way we do business.”

Lack of Uniform Understanding of SE at the Department Level

- Lack of coherent SE policy
- Lack of effective SE implementation - no “forcing function” for PM or contractor SE activities
- Program teams incentivized by cost and schedule, not execution of disciplined SE
- Products and processes not in balance (emphasis on speed; fix it in the next spiral)
- Inconsistent focus across life-cycle, particularly prior to Milestone B
- SE inadequately considered in program life cycle decisions

Lack of Uniform Understanding of SE in the Community-at-Large

- No single definition or agreement on the scope of SE
- Lack of common understanding of how SE is implemented on programs
  - Is SE done by the systems engineer?
  - Does the systems engineer lead the SE effort?
- No uniform understanding of what makes a good systems engineer
- No consistent set of metrics/measures to quantify the value of SE
- Cost and schedule estimation and risk management processes inconsistently aligned with SE processes
- Resistance to harmonization of multiple standards and models
- Multiple practioner communities not aligned
  - Hardware
  - Software
  - Information Technology
  - Telecommunications
  - Program Management

System Complexity

- System complexity is ever increasing – Moore's Law at the system scale – Family of Systems/System of Systems interdependencies
- Integrated systems (software with embedded hardware) vice platforms (hardware with embedded software)
- Network centric, spiral development, extension of system applications are driving higher levels of integration

The Resource Picture

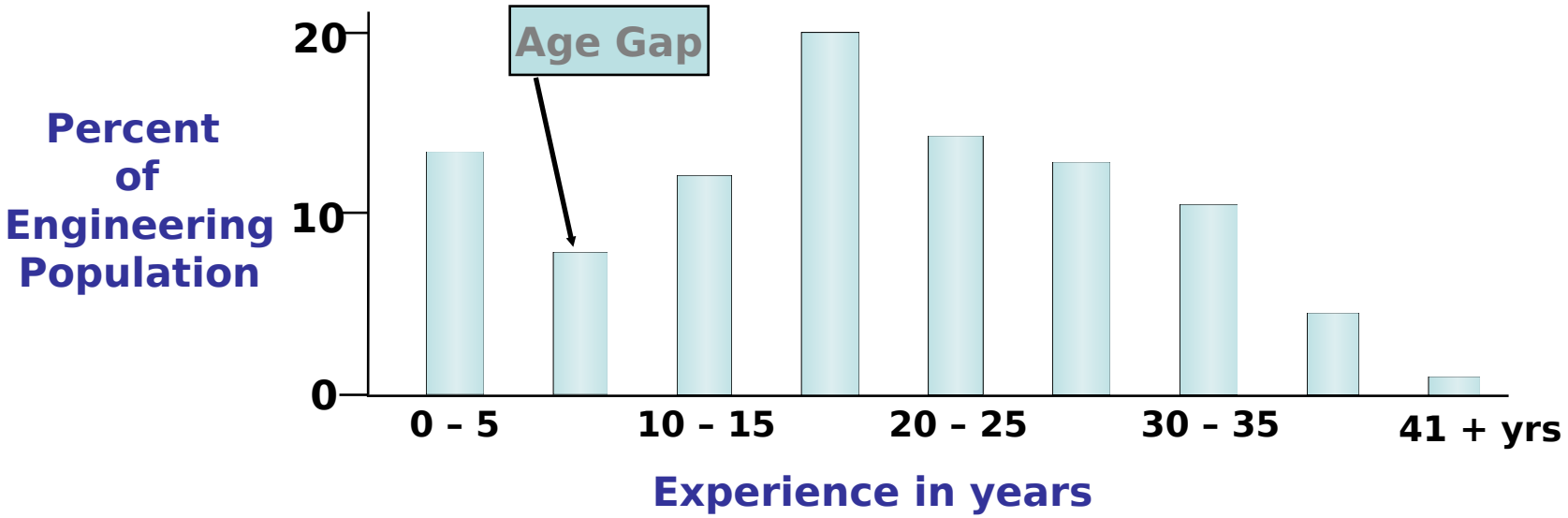
- Degreed workforce is a shrinking pool
  - Many graduates are not US citizens
  - Total engineering enrollments continue to decrease
- Ability to attract and retain young engineers in the aerospace industry is directly associated with the commercial marketplace
  - The aerospace and defense industry is seen as being overly bureaucratic and lacking in exciting technical challenges by engineering students
  - 5 year itch
- Existing university/industry partnerships are not having enough impact
  - SE is not a standard discipline (EE, ChemE, ME etc.)
  - More focus at undergraduate level
  - Do we have critical mass in terms of SE graduate level training in the U.S.?
- Need new ways to attract and develop system engineers
  - Additional learning
  - On-the-job experience

We need a better approach

Adapted from G. Shelton (Raytheon)

“We Have a Pipeline Problem”

Demographics of Engineers Years Since Bachelor of Science Degre



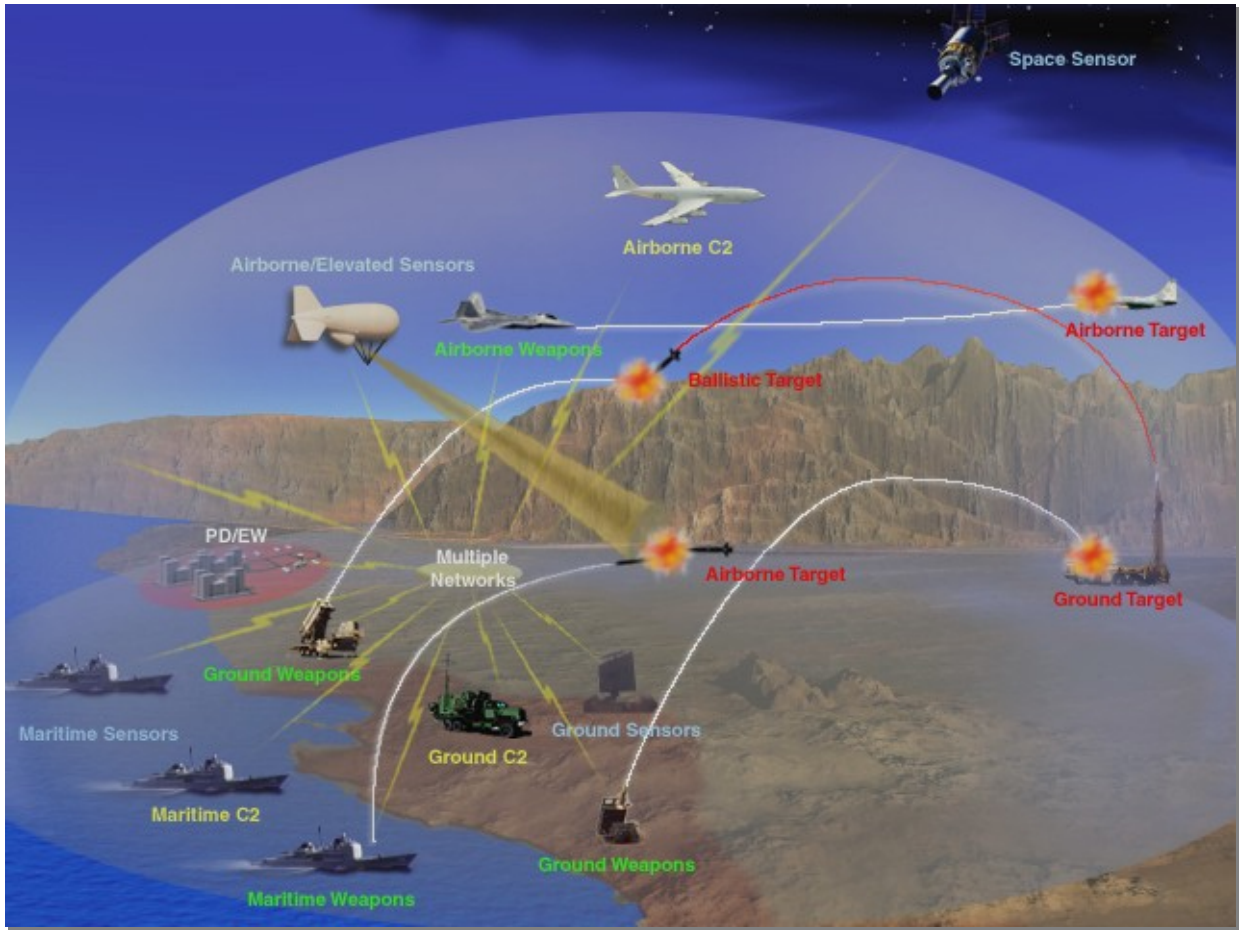
- Reduced defense expenditures in the 1990’s led to reduced hiring
  - 1990’s workforce gap has made our current situation worse
- History of a flat/declining workforce since the mid – 80’s
  - Caused “graying” of workforce
  - Loss of our knowledge base
  - Must plan for many retirements in next 5 – 10 years

Excerpted from G. Shelton (Raytheo

SE Education and Training Summit (October 2003)

- Brainstorming session
  - What's working
  - What needs to be fixed
  - Significant barriers
  - Required actions
- Formed five working groups, assigned leads
  - Policy - Al Brown, Boeing, (314)234-2337
  - Processes - Dan Dechant, Raytheon, (781)999-1662
  - Tools and guides - Phil Babel, Dayton Aerospace, (937)602-6748
  - Resources - Willie L. Blow, L-3 Comm, (903)457-4380
  - Education and training - Dinesh Verma, (210)216-8645/Donna Rhodes
- Follow-up meeting – SE Supportability And Interoperability Conference, Wed, 0900, Track 1

Our Challenge
Execute the “Big Picture”



“He thinks we can do it.”

The Problem

- The previous requirements and acquisition processes frequently produced stovepiped system solutions
  - Requirements were Service rather than Joint focused
  - Lacked construct for objective analysis
  - Systems not necessarily integrated
  - Duplication existed, particularly in smaller programs
  - Evolutionary acquisition not well institutionalized
  - Joint Warfighting needs not prioritized

“New Paradigm”

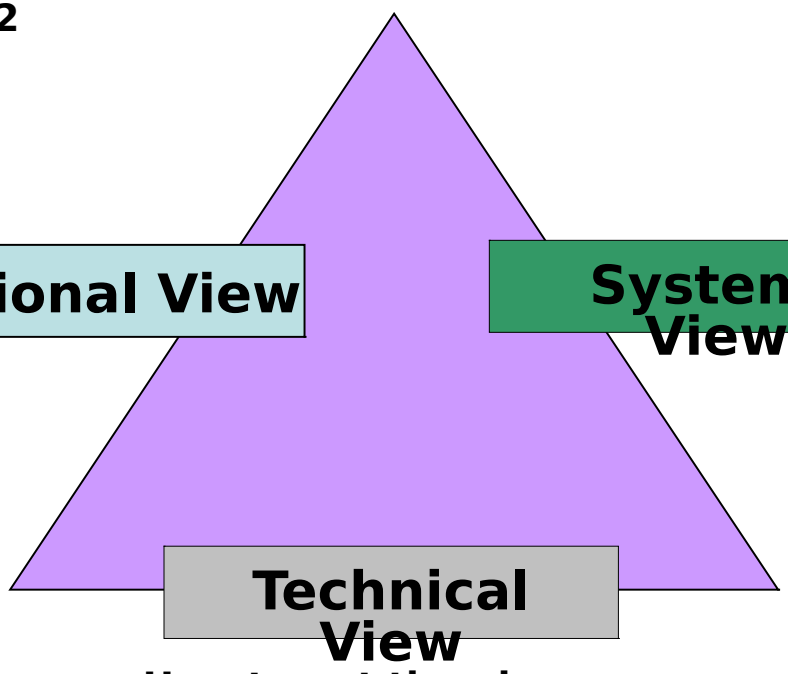
- DoD 5000 Series and CJCSI 3170.01C have been recast
- Both address **capabilities-based** approach to acquisition based on joint integrated architectures

DoD Architecture Framework

An architecture is

"the structure of components, their interrelationships, and the principles and guidelines governing their design and evolution over time."

Source: DoD Integrated Architecture Panel, 1995
Based on IEEE STD 610.12

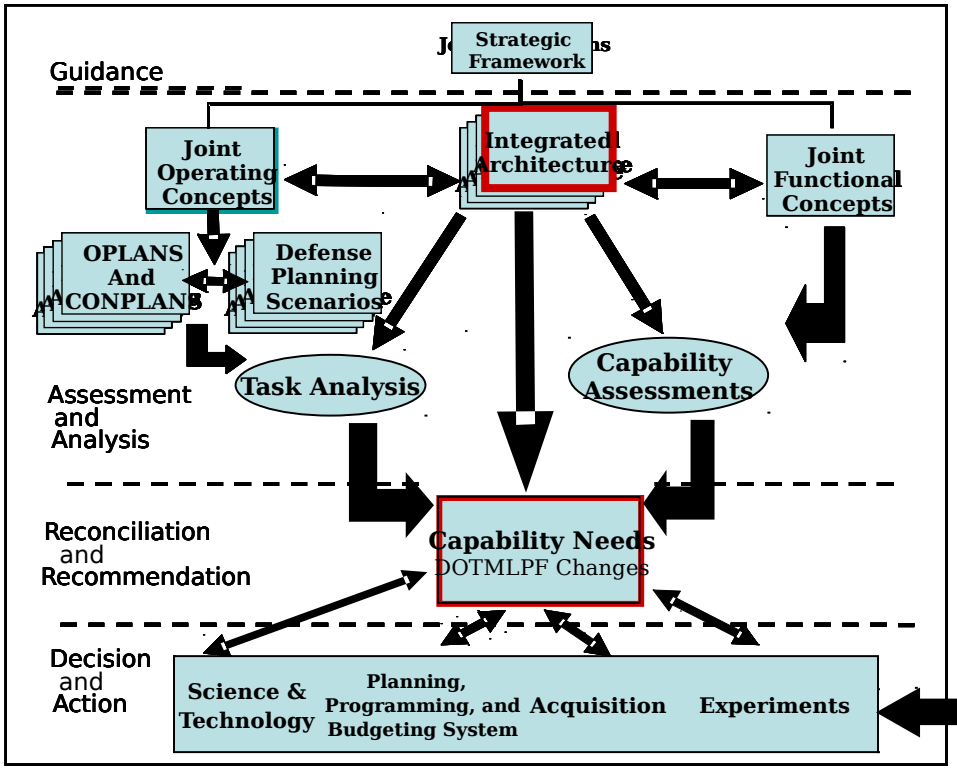


What the warfighter wants to do and how

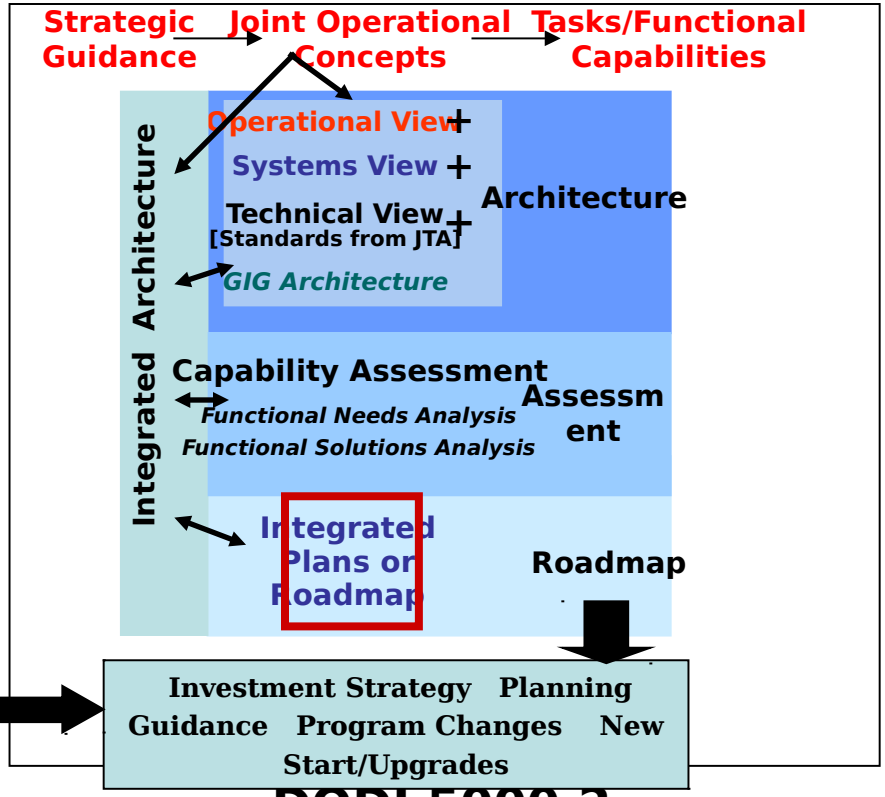
What systems to bring together and how to organize them to provide capability

How to put the pieces together

The Joint Capabilities Integration and Development System and Acquisition Processes

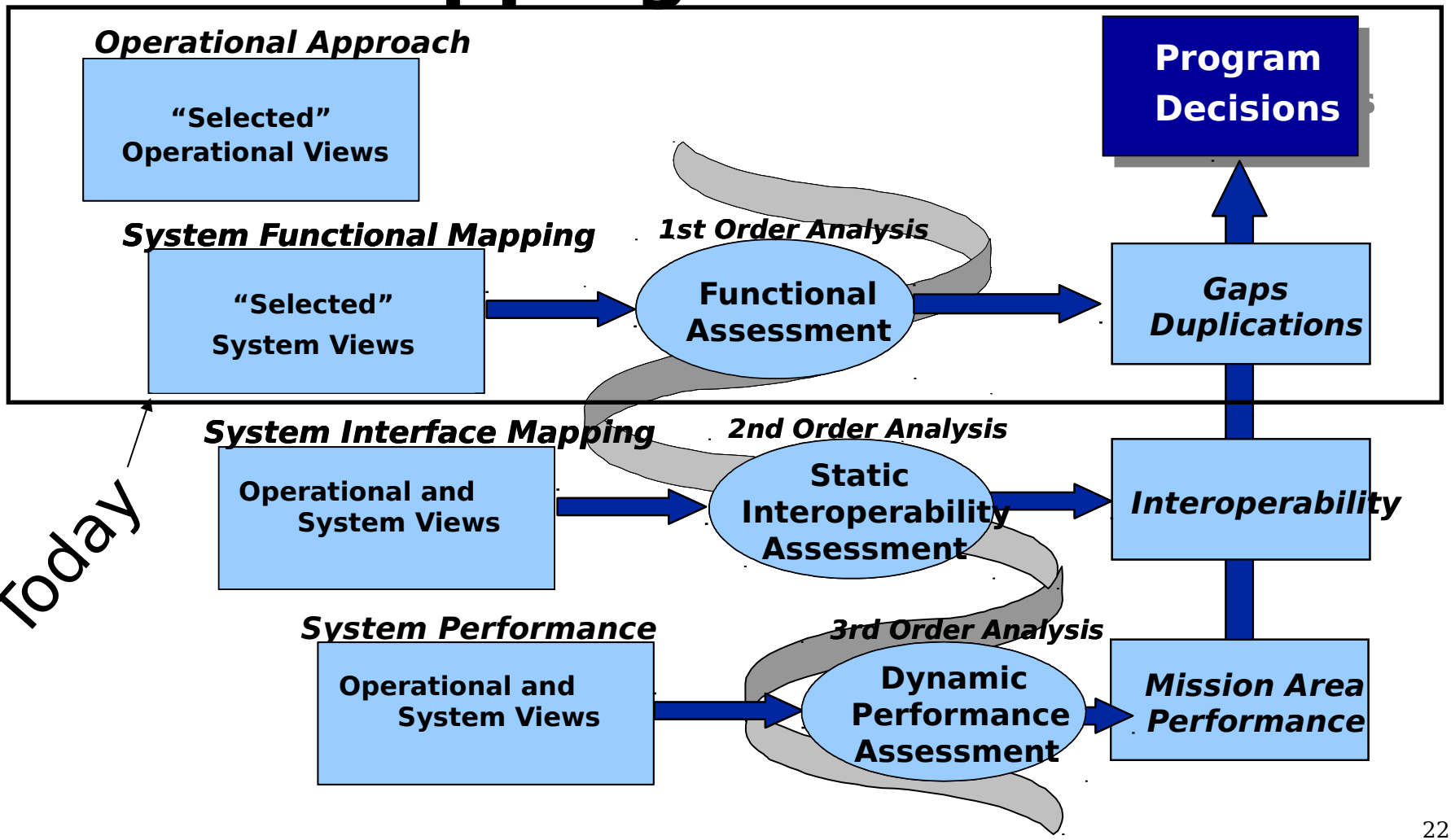


CJCSI 3170.01C
Joint Capabilities Integration and Development System



DODI 5000.2
Operation of Defense Acquisition System

Current Capability Definition, System Mapping & Assessment



But does this address all DOTMLPF aspects?

JCIDS – Acquisition Integration
A Few Things to Resolve

- Role of integrated architectures
- Scope / scale of problem
  - All capabilities, not just C4ISR
  - All systems, but to what level
  - Not just materiel solutions – DOTMLPF
  - How are cost and effectiveness integrated?
- Merger of top-down capabilities needs with bottom-up platform requirements
- Trade-off process
- Practical limitations to support decision timelines

Defense Systems "Way Ahead"

- Provide effective SE policies, practices, procedures, methods, and tools
- Improve the systems engineering environment
- Provide for a professional SE workforce
- Lead the development of systems views for an integrated architecture
- Conduct systems assessments to improve balance of cost, schedule, performance, and risk in programs

Defense Systems "Way Ahead" (cont'd)

- Reduce the life cycle cost of defense systems
- Assess system technical maturity and readiness for operational test, based on developmental test results
- Lead the development of integrated plans and/or roadmaps
- Establish a broader context for DAB reviews
- Foster interoperability, jointness, and coalition capabilities

My Challenge To You

- SE and the Services have challenges internal to the DoD
  - DoD acquisition policy, processes, methods, tools changes to enhance SE effectiveness
  - Education and training updates to reflect SE best practice
  - Application of SE to systems views and capability-based planning
  - We need industry and academia counsel as we address our internal challenges
- Industry and academia face challenges as well
  - Weakening infrastructure and resources
  - SE pipeline
  - “Critical mass” in graduate level SE education
  - Proliferation of SE standards and methods

Systems Engineering Today

- Is Systems Engineering still relevant? Absolutely
- Has the role of SE changed? Absolutely
- Are there new challenges? Absolutely
- Does Industry have a role in the evolution of DoD's SE Set of Challenges? Absolutely
- Does SE Education and Training need to change? Absolutely
- Do we have all the answers? Absolutely not!

It's a great time to be engaged with Systems Engineering!

BACKUPS

Responsibilities Spelled Out in DODI 5000

3.2.1.2. Each **integrated architecture** shall have three views: operational, systems, and technical, as defined in the current Architectural Framework guidance and have direct relationships to DoD Component-developed functional area integrated architectures.

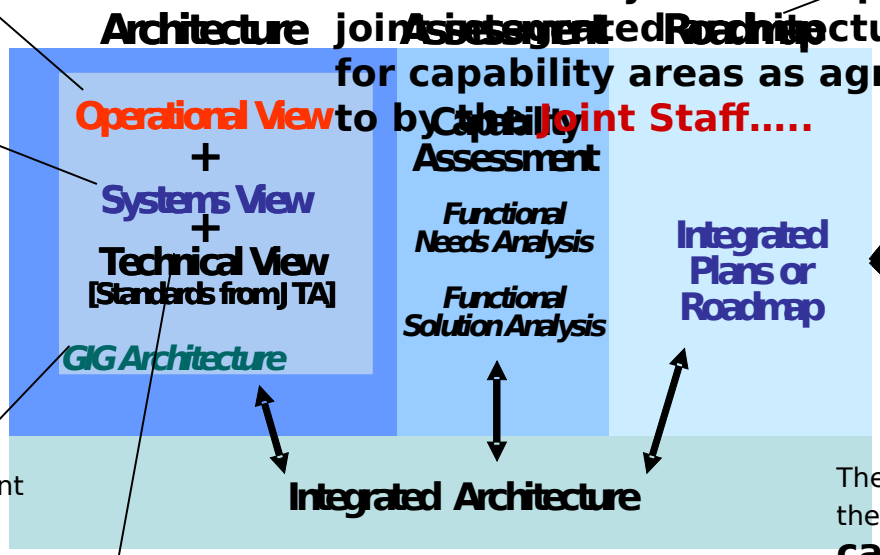
The **Joint Staff** (or Principal Staff Assistant (PSA) for business areas) shall lead development of the operational view, in collaboration with the Services, Agencies, and Combatant Commanders, to describe the joint capabilities that the user seeks and how to employ them.

The **USD(AT&L)** (or PSA for business areas) shall lead development of the systems view, in collaboration with the Services, Agencies, and Combatant Commanders, to characterize available technology and systems functionality. The systems view shall identify the kinds of systems and integration needed to achieve the desired operational capability.

The **DoD Chief Information Officer (CIO)** shall lead the development and facilitate the implementation of the Global Information Grid Integrated Architecture, which shall underpin all mission area and capability architectures.

3.2.1.1. The Under Secretary of Defense (Acquisition, Technology, and Logistics) (**USD(AT&L)),** the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence (**ASD(C3I**)), the **Joint Staff**, the **Military Departments**, the **Defense Agencies**, **Combatant Commanders**, and other appropriate DoD Components shall **work collaboratively to develop joint integrated architectures for capability areas as agreed to by the Joint Staff…..**

3.2.2. Integrated Capability Assessments, Capability Roadmaps, and Investment Strategies. Using the integrated architectures, the **USD(AT&L)** shall lead the development of **integrated plans or roadmaps**.



The Military Departments and Defense Agencies shall participate in the identification of the appropriate technical view consisting of standards that define and clarify the individual systems technology and integration requirements. The standards used to form the Technical Views of integrated architectures shall be selected from those contained in the current approved version of the **Joint Technical Architecture…**

The Department of Defense shall use these roadmaps to **conduct capability assessments, guide systems development, and define the associated investment plans** as the basis for aligning resources and as an input to the Defense Planning Guidance, Program Objective Memorandum development, and

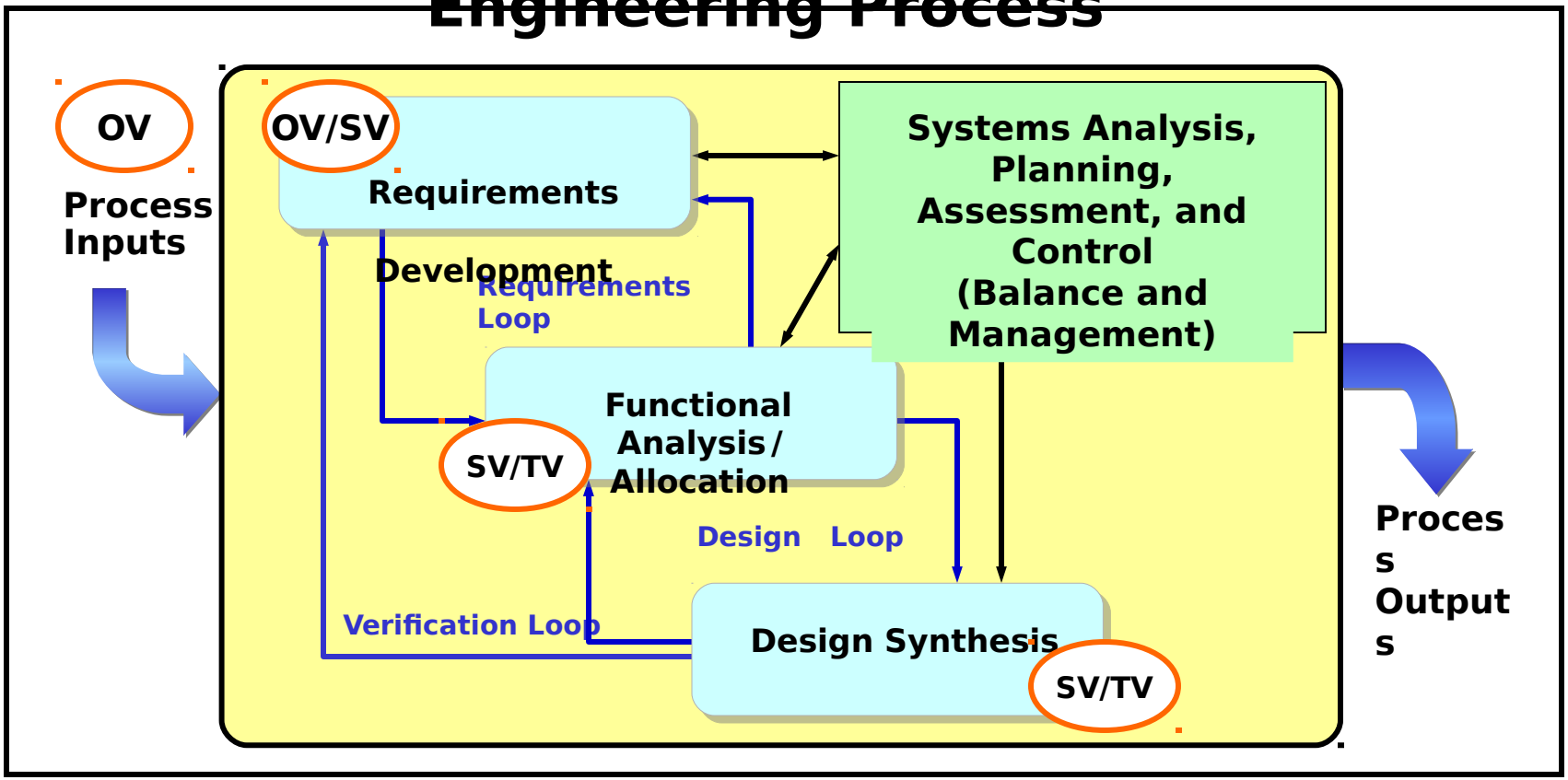
The DoD Architecture Framework

- New paradigm for establishing capabilities “top-down”
  - Draws heavily on C4ISR Framework
  - Part of process is development of integrated architectures
  - Architectures become a tool for a common view of integrated battlespace system of systems, shared by warfighters, acquirers, developers
- DoDAF is architecture modeling framework
  - Developed for information architectures for CIO requirments
  - In context of new CJCSCI 3170/DoD 5000, intended to address broader joint warfighting issues
  - Not only information exchange needs, but also to frame decisions concerning mix of systems needed

SoS Systems Engineering Process Applies From SoS to System/Component Level

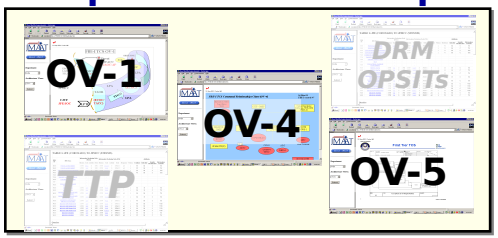
- Same methods uses at each system level to:
  - Define the requirements and architecture at each level in a common notation
  - Direct trade studies performed at each level of the architecture
  - Coordinate the inter-disciplinary transfer of requirements
  - Eliminate the model gap between SE, other disciplines, and tools
  - Support software development at all levels of the architecture

DoD Architectural Framework Mapped into the Systems Engineering Process



OV – Operational View
SV – Systems View
TV – Technical Standards View

Operational Concept



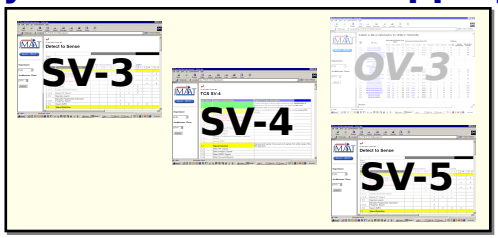
Functional Architecture

The Role of Engineering and Technology

Physical Architecture

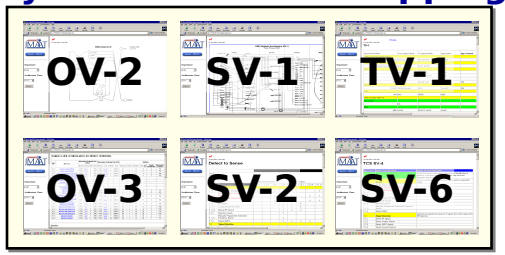
CV-6	Capabilities Evolution Description
OV-1	High-level Operational Concept Graphic
OV-2	Operational Node Connectivity Description
OV-3	Operational Information Exchange Matrix
OV-4	Command Relationships Chart
OV-5	Activity Model
OV-6C	Operational Event/Trace Description
SV-1	System Interface Description
SV-2	Systems Communication Description
SV-3	Systems Matrix
SV-4	System Functionality Description
SV-5	Operational Activity to System Function Traceability Matrix
SV-6	System Information Exchange Matrix
SV-7	System Performance Parameters Matrix
SV-8	System Evolution Description
SV-9	System Technology Forecast
SV-10	System Activity Sequence & Timing
TV-1	Technical Architecture Profile
TV-2	Standards Technology Forecast

System Functional Mapping



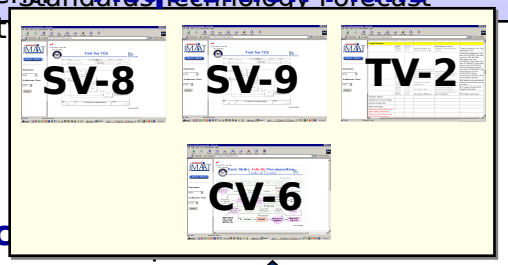
1st Order Assessment: Functionality

System Interface Mapping



2nd Order Assessment: Static Interoperabilit

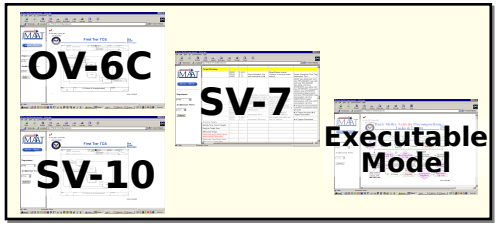
Acquisition Plans



DRM: Design Reference Mission
OPSIT: Operational Situation
TTP: Tactics, Techniques, Procedures

Note: There are dependencies between the Architecture products that are not shown in the System Engineering flow. Many of the products are developed concurrently.

Architecture Performanc and Behavior



3rd Order Assessment: Dynamic Interoperability

Architectures Provide the Framework and Assessment for FoS/SoS Systems Engineering

Source: Mr. Steve Soules, Booz-Allen & Hamilton

Architectural Challenges for Systems Engineering

DoDAF Architecture
- DoD Level
- Top-Down
- Battlefield/SoS/FoS focused

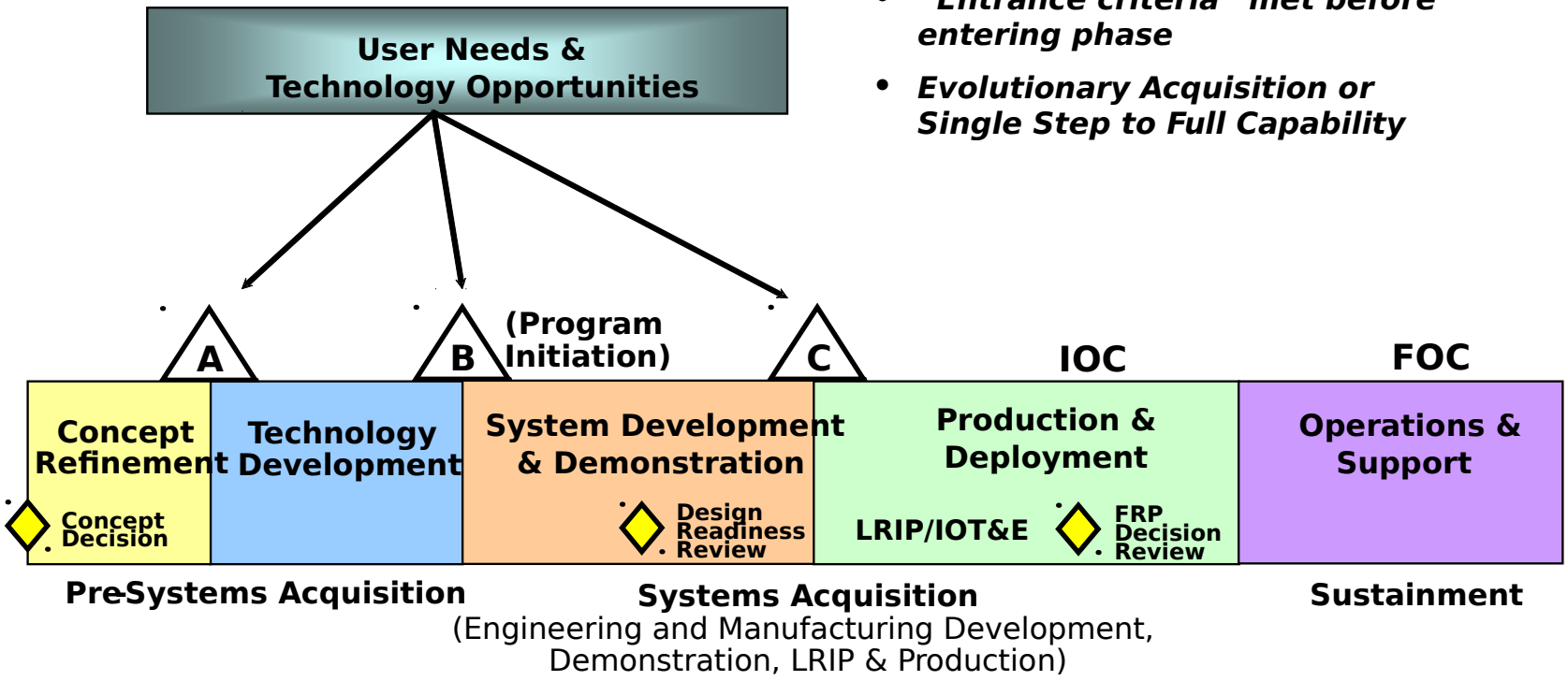
DoD Acquisition
- Service Level
- Bottom-Up (Cost/ Schedule/Performance of a System

Architecture Gap/SE Challenge

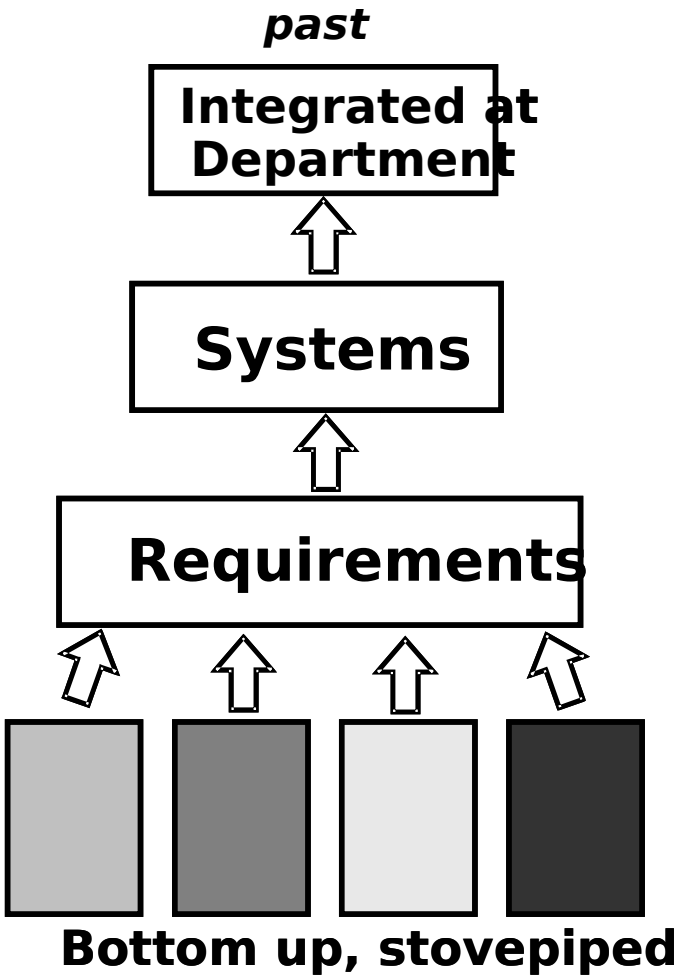
- How to DoDAF to address more than interoperability capabilities
- How to translate and decompose desired SoS/FoS capabilities into system-level technical requirements
- How to assess potential capabilities among new technologies and legacy technologies/systems

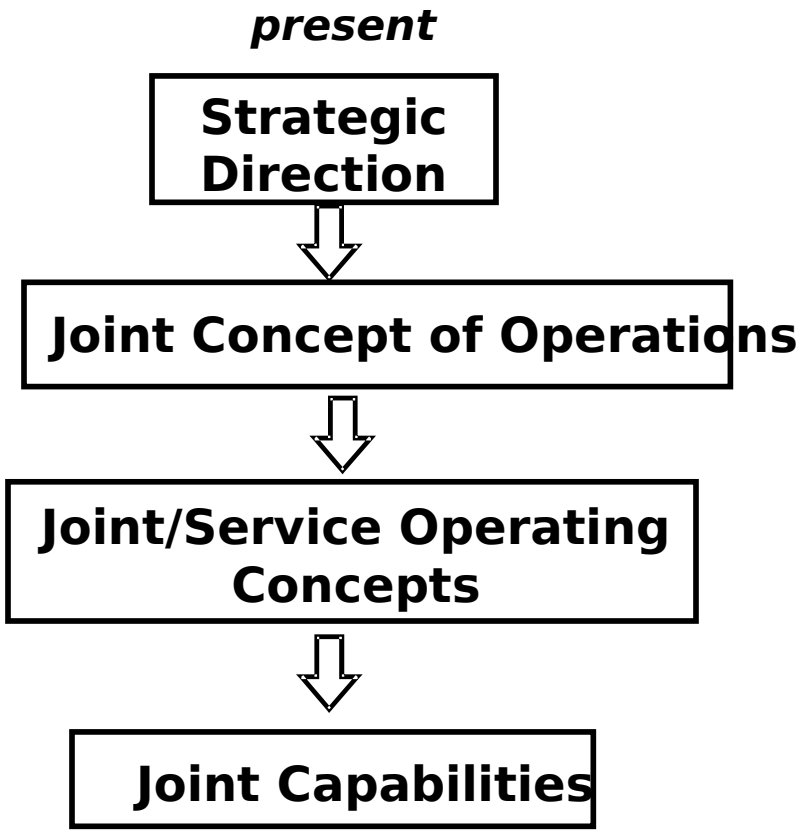
The Acquisition Model
DoDD 5000

- ***Process entry at Milestones A, B, or C (or within phases)***
- ***"Entrance criteria" met before entering phase***
- ***Evolutionary Acquisition or Single Step to Full Capability***



Requirements Basis





Limitations of DoDAF (From SE Perspective)

- May not support planned JCIDS analyses
  - DOTMLPF
  - Analysis of alternatives
  - Life cycle cost
  - System effectiveness
- May not address system retirement/decommissioning – time dimension
- May not address all system aspects needed for investment decisions
  - Manpower
  - Supportability & logistics
  - Ownership cost
- May not be supported by a development process
- Data complexity may reduce utility when applied at the FoS level